DOCUMENT RESUME

ED 431 595 SE 062 489

AUTHOR Truelove, Elizabeth; Dejoie, Joyce

TITLE Starchild Presents...StarChild: A Learning Center for Young Astronomers. Black Holes. An Information and Activity Booklet. Grades K-8, 1998-1999.

INSTITUTION National Aeronautics and Space Administration, Greenbelt, MD. Goddard Space Flight Center.

REPORT NO NP-1998(08)-039-GSFC

PUB DATE 1998-00-00

NOTE 34p.; For secondary school activity booklet, see SE 062 490. CD-ROM and poster not available from ERIC.

AVAILABLE FROM Web site: http://starchild.gsfc.nasa.gov

PUB TYPE Guides - Classroom - Teacher (052) -- Non-Print Media (100)

EDRS PRICE MF01/PC02 Plus Postage.

DESCRIPTORS *Astronomy; Elementary Education; Gravity (Physics); *Integrated Activities; Light; Physics; Science Instruction; Scientific Concepts; *Space Sciences; Stars

IDENTIFIERS *Black Holes

ABSTRACT

The information provided in this booklet is meant to give the necessary background information so that the science of black holes can be taught confidently to elementary students. The featured activities can be used to engage and excite students about the topic of black holes in different disciplines and in a number of ways. Activities include: (1) Black Hole Gridlock; (2) Binary Buddies; (3) Supermassive Sums; (4) The Hole Story; (5) Match Me If You Can; (6) Spelling Stars; (7) Diagramming Dilemma; (8) Star Routes; (9) Intergalactic Integers; (10) Diamonds in the Sky; (11) Scientific Notables; and (12) Slopes, Stars, Supernovae, and Stuff. A CD-ROM and poster accompany the guide. (WRM)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED 431 595

An Information & Activity Booklet

Grades K-8

1998-1999

StarChild - a Learning Center for Young Astronomers

NP-1998(08)-039-GSFC

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)
☑ This document has been reproduced as received from the person or organization originating it.
☐ Minor changes have been made to improve reproduction quality.
• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

BEST COPY AVAILABLE

SE 060 489

STARCHILD **presents...**

BLACK HOLES

WRITTEN BY:

Dr. Elizabeth Truelove and Mrs. Joyce Dejoie
Lakeside Middle School
Evans, Georgia

This booklet, along with its matching poster, is meant to be used in conjunction with the StarChild Web site or CD-ROM.
http://starchild.gsfc.nasa.gov/

TABLE OF CONTENTS

Table of Contents i

Association with National Mathematics and Science Standards ii

Preface 1

Black Holes
- Stellar Black Holes 2
- Supermassive Black Holes 3

Level 1 Activities

- Black Hole Gridlock 4
- Binary Buddies 5
- Supermassive Sums 6
- The Hole Story 7
- Match Me If You Can 11
- Spelling Stars 12

Level 2 Activities

- Diagramming Dilemma 13
- Star Routes 14
- Intergalactic Integers 15
- Diamonds in the Sky 16
- Scientific Notables 17
- Slopes, Stars, Supernovae, and Stuff 19

Solutions 20

About the Poster 26

Resources 27

NATIONAL MATHEMATICS AND SCIENCE STANDARDS FOR THE ACTIVITIES IN THIS BOOKLET

BLACK HOLE GRIDLOCK
- NCTM Grades K-4 Standards 1,3,4,9, and 13
- NSES Content Standards A, B, and D for Grades K-4

BINARY BUDDIES
- NCTM Grades K-4 Standards 1 and 9
- NSES Content Standards A, B, D, and E for Grades K-4

SUPERMASSIVE SUMS
- NCTM Grades K-4 Standards 1, 3, 4, 7, and 8
- NSES Content Standard A for grades K-4

THE HOLE STORY
- NSES Content Standards A, B, D, E, and F for Grades K-4

SPELLING STARS
- NSES Content Standard A for Grades K-4

MATCH ME IF YOU CAN
- NSES Content Standards A, B, and D for Grades K-4

DIAGRAMMING DILEMMA
- NCTM Grades 5-8 Standards 1, 2, and 3
- NSES Content Standards A, B, E, and G for Grades 5-8

STAR ROUTES
- NCTM Grades 5-8 Standards 1, 2, 3, and 7
- NSES Content Standard A for Grades 5-8

INTERGALACTIC INTEGERS
- NCTM Grades 5-8 Standards 1, 5, 6, and 7
- NSES Content Standard A for Grades 5-8

DIAMONDS IN THE SKY
- NCTM Grades 5-8 Standards 1, 2, 3, 4, and 12
- NSES Content Standards A and G for Grades 5-8

SCIENTIFIC NOTABLES
- NCTM Grades 5-8 Standards 1, 2, 4, 5, 6, 7, 8, and 13
- NSES Content Standards A and B for Grades 5-8

SLOPES, STARS, SUPERNOVAE AND STUFF
- NCTM GRADES 5-8 Standards 1, 2, 3, 4, 5, 6, 7, 8, and 13
- NSES Content Standard A for Grades 5-8

PREFACE

WELCOME to the second in a series of posters and activity booklets produced in conjunction with the *StarChild* Web site. The poster/booklet sets are intended to provide additional curriculum support materials for some of the subjects presented in the Web site. The information provided for the educator in the booklet is meant to give the necessary background information so that the topic can be taught confidently to students. The activities can be used to engage and excite students about the topic of black holes in a number of disciplines and ways. All activities can be photocopied and distributed for educational, non-commercial purposes!

For additional materials and information, visit the *StarChild* Web site at http://starchild.gsfc.nasa.gov/. We also look forward to hearing your opinions about this poster/booklet set! Our email address is starchild@heasarc.gsfc.nasa.gov.

BLACK HOLES

American physicist John Archibald Wheeler first coined the term "black hole" in 1967. Before the adoption of the term by Wheeler, the objects now known as black holes were referred to as frozen stars, dark stars, or collapsed stars. Black holes come in all sizes. Stellar black holes are the result of massive stars dying. Supermassive black holes are believed to have been created during the early Universe. The exact mechanism by which they were created is under debate. Some scientists believe in the existence of mini-black holes that were created at the same time as the Universe. This type of black hole, they maintain, is the approximate size of an atom yet has the mass of a large mountain. No matter what the size of a black hole, they all share a common characteristic; not even light can escape their gravitational pull. Though black holes have probably been around since the Universe began, only recently have we begun to learn in-depth information about them. In the last few decades astronomers began to look at the Universe in the radio, infrared, ultraviolet, X-ray, and gamma-ray regions of the electromagnetic spectrum and have been able to gather much more black hole data.

STELLAR BLACK HOLES

Astronomers suspect that most black holes are produced when massive stars (at least 8-10 times the Sun's mass) reach the end of their lifecycle. Inside a star, gravity tries to pull matter closer together. While a star is glowing, it is consuming its fuel through a nuclear process known as fusion. It radiates not only light, but heat as well. The pressure of the heated gases pushing outward balances the force of gravity pulling inward. Once the star's nuclear fuel has been depleted, the star becomes unstable and the core implodes causing the outer shell to explode in a supernova. If the remnant core that remains after the supernova is less than 3 solar masses, gravity compresses the electrons and protons so that neutrons form. The pressure of neutrons in contact with each other counteracts the forces of gravity. This stable core, which is now composed almost entirely of neutrons, forms a neutron star. Neutron stars possess tremendous mass and consequently have a very powerful gravitational pull. If the remnant left after the supernova is greater than 3 times the Sun's mass, not even the neutron pressure can counteract gravity and the remaining material will continue to contract. The remnant collapses to the point of essentially zero volume (yet it has infinite density!). This creates a mathematical singularity. A singularity resides in the center of all black holes.

A spherical region known as the event horizon marks what scientists call the "boundary" of a black hole. It is given this name because information about events which occur inside this region can never reach us. The distance from the singularity to the event horizon is known as the Schwarzschild radius, after the German physicist who predicted the existence of a "magic sphere" around a very dense object. Inside the region, he theorized, gravity would be so powerful that nothing could escape from it, i.e., the gravitational pull would be so strong that the velocity necessary to escape the pull is unobtainable. A black hole has such an enormous concentration of mass in such a small volume that in order to escape from it, an object would have to be moving at a speed greater than the speed of light. At this time we know of nothing that can attain the necessary velocity.

Remember that a stellar black hole was once a star. Most stars have a companion star to which they are bound in a binary system. This nearby companion can be a source of material on which the black hole "feeds". Matter can be pulled off the companion in large swirling streams of hot gas that spiral toward the black hole as a fast moving incandescent whirlpool known as an accretion disk. As the matter in the disk falls closer to the black hole, it heats up and gives off radiation such as X-rays. By measuring the motion and radiation from an accretion disk, astronomers are able to infer the presence and mass of the black hole. When all of the material in the accretion disk has been consumed, the disk disappears and the black hole is virtually undetectable. Stars and planets at a safe distance from the black hole's event horizon will not be pulled in toward the black hole. They will instead orbit the black hole just as the planets orbit the Sun in our solar system. The gravitational force on stars and planets orbiting a black hole is the same as when the black hole was a normal star.

SUPERMASSIVE BLACK HOLES

Supermassive black holes have masses comparable to those of a typical galaxy. These masses range anywhere from 10 billion to 100 billion of our Suns. Supermassive black holes tend to be in the centers of galaxies, creating what are called Active Galactic Nuclei (AGNs). An AGN emits more energy than would be expected from a typical galactic nucleus. The answer as to why this is so lies in the presence of the supermassive black hole in the galactic center. In some AGN, the massive black hole and its accretion disk somehow produce outward-moving streams of particles that are projected away perpendicular to the disk. These streams are known as jets and have the power to accelerate electrons almost to the speed of light. This produces gamma-rays that can be detected by gamma-ray observatories. The most powerful AGNs in our Universe are called quasars. We have been able to detect quasars that reside 15 billion light-years away. Scientists believe that the study of quasars will provide information about the Universe during the time of early galaxy formation.

BLACK HOLE GRIDLOCK - LEVEL 1

Locate each word from the black hole word bank on the grid below. Circle the word. Rewrite each word in a column under the grid. Beside each word write the number-letter coordinate of each letter in the word. Example: Mom = A12 A11 A10

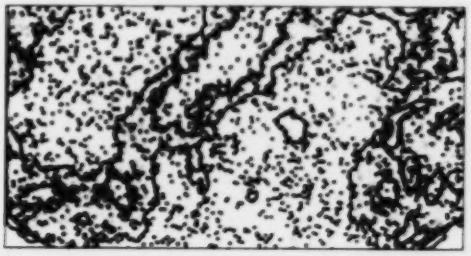
BLACK HOLE WORD BANK:

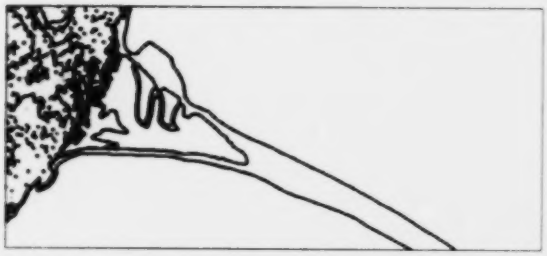
star	pull	hot
matter	gravity	jet
fuel	light	
X-ray	mass	

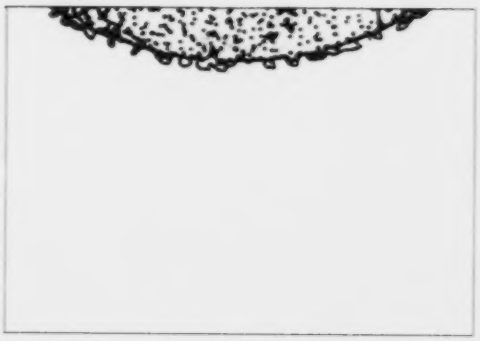
12	m	w	r	t	y	u	g	j
11	o	a	t	x	r	a	y	g
10	m	d	t	c	b	a	e	r
9	t	y	u	t	s	c	b	a
8	p	u	l	l	e	q	m	v
7	n	v	c	z	w	r	w	i
6	w	i	o	p	d	g	f	t
5	j	s	e	t	h	s	u	y
4	e	a	t	s	s	j	e	n
3	t	q	t	a	i	p	l	f
2	s	o	m	f	r	v	c	n
1	h	m	z	l	i	g	h	t
	A	B	C	D	E	F	G	H

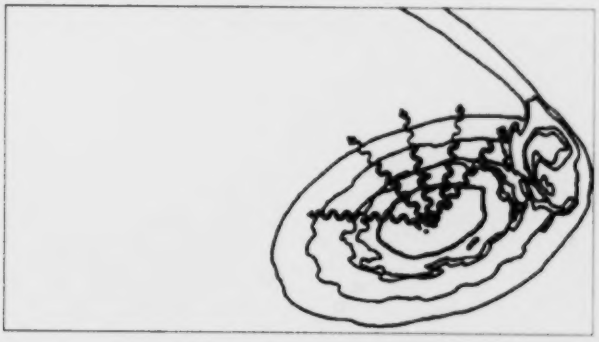
BINARY BUDDIES - LEVEL 1

Cut out the five pieces below. Paste the pieces together on another sheet of paper in order to see the completed picture. Color your picture. (HINT: Your completed picture will show material from a nearby star being pulled into a black hole.)









SUPERMASSIVE SUMS - LEVEL 1

In each block you will find a letter and its value. For each word, add the value of the letters. Your mission is to find the sum of each word. Example: black = 3+7+0+2+4 = 16

0 a	3 b	2 c	5 d	6 e	9 f	2 g
1 h	4 i	6 j	4 k	7 l	1 m	3 n
7 o	8 p	9 q	1 r	3 s	10 t	4 u
5 v	10 w	2 x	5 y	8 z	6 -	*

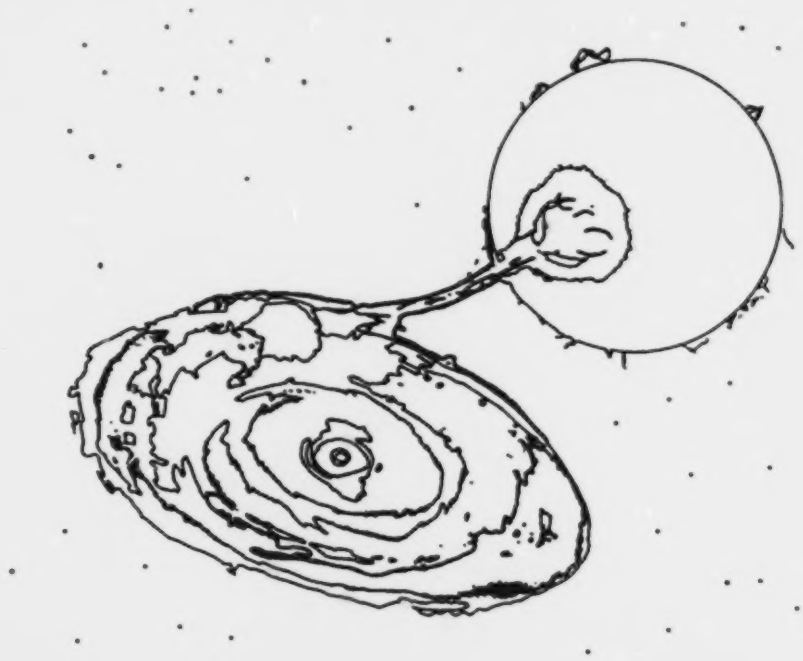
1. dust
2. gas
3. disk
4. jets
5. mass
6. star
7. Sun
8. X-ray
9. heat
10. hole

CHALLENGE:

11. gravity
12. quasar
13. gamma-ray
14. universe
15. remnant

THE HOLE STORY - LEVEL 1

Color the black hole picture below. Draw and color a picture to go with the black hole sentence in each block. Cut out the blocks on the dotted lines. Put the sentence blocks in number order, with the title page on top. Staple the blocks together to the space below to make your black hole book.



Staple the pages here

6
Black holes are very small but they can pull in anything that comes too close.

8
Scientists know black holes are there because they can measure radiation given off when something falls into a black hole.

7
Black holes cannot be seen directly.

13

3
The explosion is called a supernova.

5
Gravity squeezes the left over piece together until it is smaller than a pencil point.

1
Only very, very big stars (called massive stars) can become black holes.

2
After a massive star uses all its fuel, it explodes.

4
A black hole can be made if a piece heavier than three Suns is left after the supernova.

My Black Hole Book
by

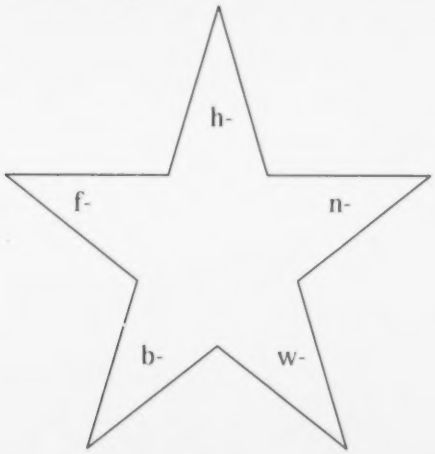
MATCH ME IF YOU CAN - LEVEL 1

Draw a line to match each vocabulary term with its definition.

supernova	a very dense star made up of neutrons
implosion	the point at the center of a black hole
escape velocity	the shrinking of a star caused by the pull of its own gravity
binary system	the speed at which an object must travel to escape the gravitational pull of another object
singularity	an explosion of a star that causes the star to shine a million times brighter than before
Universe	a process where atoms are joined and tremendous amounts of energy are released
accretion disk	two objects in orbit around each other
nuclear fusion	the huge space that contains all the matter and energy in existence
neutron star	a spiral of gas that can surround a black hole
event horizon	the spherical distance surrounding a black hole out of which nothing can escape

SPELLING STARS - LEVEL 1

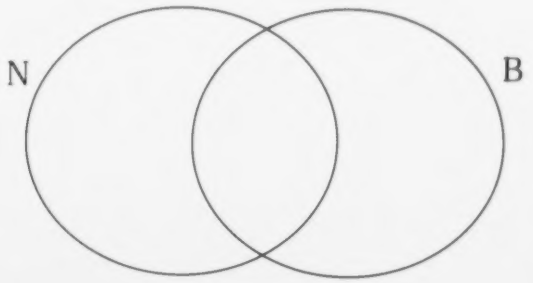
Put a letter from the left star together with the letter combinations from the star on the right to make a word. See how many different words you can make. Write each word you make on a line below the starting letter.



b	f	h	n	w
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____		_____	_____	_____
_____				_____

DIAGRAMMING DILEMMA - LEVEL 2

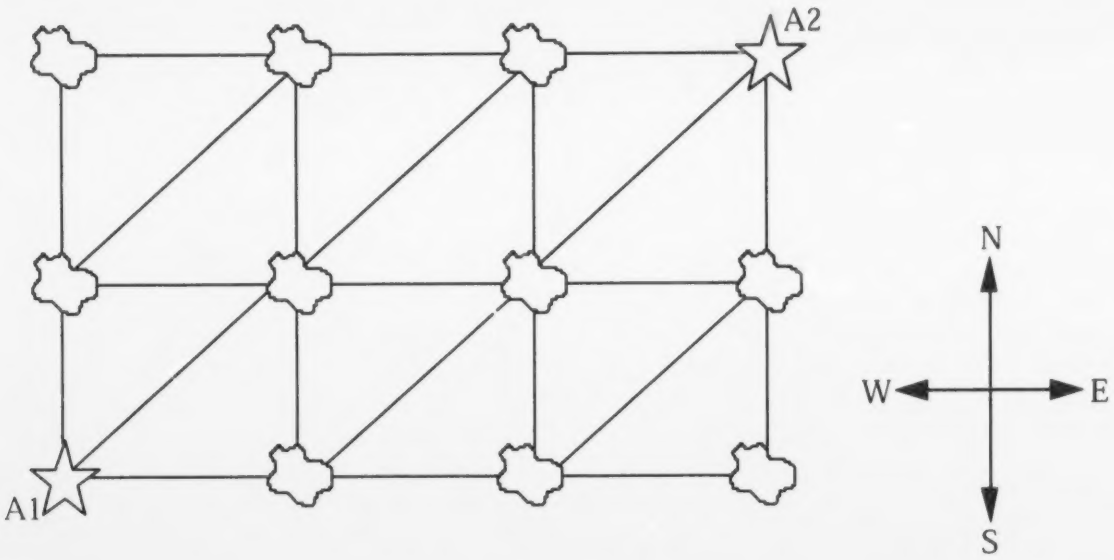
Venn diagrams are often used to organize information that compares and contrasts two or more different objects. In our diagram, circle B represents black holes while circle N represents neutron stars. Carefully read over the list of descriptive phrases found below. The number of a phrase that describes both a neutron star and a black hole should be written in the overlapping section of the two circles. The number of a phrase that describes only a black hole should be written in the non-overlapping section of circle B. The number of a phrase that describes only a neutron star should be written in the non-overlapping section of circle N.



1. escape velocity is greater than the speed of light
2. have been called frozen stars
3. endpoint of a star's lifecycle
4. composed of a collapsed stellar remnant of less than 3 solar masses
5. boundary marked by an event horizon
6. was once a massive star
7. has essentially zero volume
8. does not glow brightly in optical light
9. has a core composed mainly of neutrons
10. has a very powerful gravitational pull

STAR ROUTES - LEVEL 2

The map below shows stars, asteroids, and the different routes that can be taken in order to travel from Star A1 to its companion star, Star A2. If you are only allowed to travel north, northeast, or east, how many possible routes exist between the members of this binary star system?



INTERGALACTIC INTEGERS - LEVEL 2

Contained in each block is a letter along with its assigned value. Sum the values of the letters of each word into their total numerical value. Perform the designated operations to find a total value for the terms in each problem.

Example: radio - wave = (8+12-13-1+10) - (2+12+6+1) = -5

12 a	1 b	-2 s	6 v	-5 p	-9 z	0 h
-1 i	-3 m	5 u	-8 j	7 g	-4 -	3 q
2 w	13 y	-6 e	*	9 k	-12 t	-13 d
-10 f	-7 n	11 x	10 o	-11 c	8 r	4 l

1. star - dust = ?
2. gravity - neutron = ?
3. gamma-ray + X-ray = ?
4. light - hole = ?
5. quasar - galaxy = ?
6. universe + remnant = ?
7. light-year + mass = ?
8. jets - gas = ?
9. binary + matter + orbit = ?
10. black - dense - radio = ?

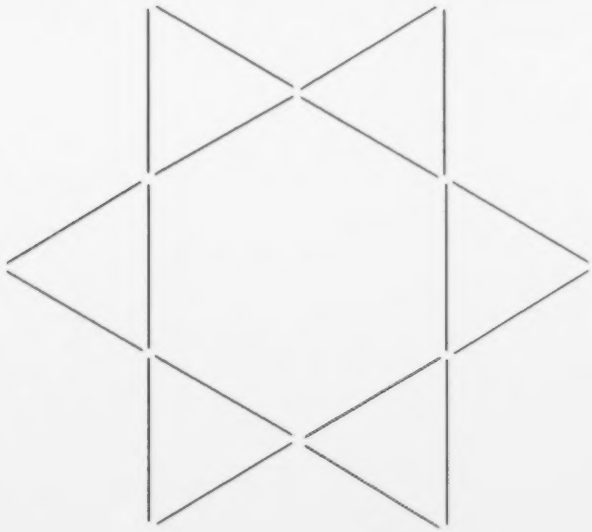
CHALLENGE: (Spaces between words have no value.)

1. Active Galactic Nuclei - event horizon = ?
2. companion star + Schwarzschild radius = ?
3. escape velocity - accretion disk = ?
4. supermassive black hole - stellar black hole = ?
5. gravitational pull + electromagnetic spectrum = ?

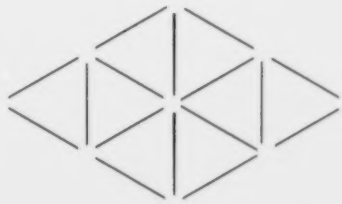
DIAMONDS IN THE SKY - LEVEL 2

Puzzles such as the ones shown here are an important part of the Chinese folk culture. These puzzles have been passed down for centuries from one generation to the next.

Below is a 6-pointed star. The star can be changed into 6 diamonds by moving 6 sticks. Decide what 6 sticks should be moved in order to accomplish this supermassive feat.



Consider the pattern below. Move 4 sticks so that the result is 6 diamonds. Choose the 4 sticks carefully as you puzzle your way to new heights!



SCIENTIFIC NOTABLES - LEVEL 2

The following activity is designed as practice with the use of scientific notation.

Working with large numbers such as galactic distances can be very time consuming. It is often more useful to express large numbers in terms of powers of 10 known as scientific notation.
Example: 1,000,000 = 1.0×10^6 (10^6 means 10x10x10x10x10x10 =1,000,000)
Notice that the decimal place has been moved 6 places to the left leaving only 1 number in front of the decimal.

1. The Sun is 150,000,000 kilometers from Earth. Convert 150,000,000 into scientific notation.

2. One light-year equals 9,500,000,000,000 kilometers. Convert 9,500,000,000,000 into scientific notation.

Any number less than 1 can also be converted into scientific notation. This time the decimal is moved to the right and the exponent becomes negative.
Example: .053 = 5.3×10^{-2} (10^{-2} means .1x.1 = .01, .01x5.3 = .053)
Notice the decimal was moved two places to the right.

3. The diameter of a singularity is .00000000000000000000000000000001 centimeters. Convert this value into scientific notation.

4. The average wavelength of an ultraviolet ray is 600 nanometers. Convert this to millimeters and then place the value in scientific notation. (1 nanometer = .000001 millimeters)

To add or subtract numbers in scientific notation, the numbers must all be written to the same power of 10.
Example: $2.6 \times 10^3 + 0.2 \times 10^1$ is the same as $2.6 \times 10^3 + 2.0 \times 10^3 = 4.6 \times 10^3$

5. Jupiter is 778.3 million kilometers from the Sun. Saturn is 1.429 billion kilometers from the Sun. Place these numbers in scientific notation and determine the minimum distance from Jupiter to Saturn.

6. Billions of years ago, colliding or merging stars may have resulted in the formation of supermassive black holes. If a star with a mass of 65 million Suns merged with a star that had a mass of 1.5 billion Suns, what would be the combined mass involved in the merger? Place all numbers in scientific notation prior to performing the necessary operation.

When multiplying, the powers of 10 are added together.
Example: $(3 \times 10^3)(2 \times 10^4) = 6 \times 10^7$

When dividing, the powers of 10 are subtracted.
Example: $\frac{4.2\times10^{6}}{2.1\times10^{2}} = 2\times10^{4}$

To calculate the density of an object the following equation is used:

$$D = \frac{M}{V}$$

where D = density, M = mass, and V = volume.

7. Calculate the density of the Sun. mass = 1.989×10^{33} g volume = 1.41×10^{33} cm^3

8. Calculate the density of a white dwarf star. mass = 1×10^{33} g volume = 5.23×10^{26} cm^3

9. Calculate the mass of a neutron star. density = 6.55×10^{14} g/ cm^3 volume = 3.05×10^{18} cm^3

CHALLENGE:
A teaspoon has a volume of 1.5 cm^3. Using the density in problems 7, 8, and 9 above, determine how much mass would be contained in 5 teaspoons of each object.

SLOPES, STARS, SUPERNOVAE, AND STUFF - LEVEL 2

Locate each of the words on the grid below from the black hole word bank. Note the numerical coordinates of the first letter and the last letter of each word. Using the following formula:

$$s = \frac{y_2 - y_1}{x_2 - x_1}$$

where s = slope, y = the y coordinates, and x = the x coordinates, calculate the slope of the line that can be drawn between the endpoints for each word. NOTE: Words are allowed to bend! They are not just horizontal, vertical, and diagonal.

WORD BANK:

gravitational	accretion disk	binary
whirlpool	singularity	quasar
detect	supermassive	
fusion	event horizon	
companion	X-ray	

Y

20	q	a	e	r	t	y	i	o	p	k	m	j	g	v	z
19	q	g	e	f	j	k	a	x	g	p	l	r	i	h	w
18	p	o	r	l	s	d	t	v	o	c	a	s	u	u	m
17	z	x	a	a	c	v	b	o	n	h	c	g	f	e	y
16	w	e	r	t	v	h	l	j	k	l	o	p	o	i	n
15	a	q	w	s	x	i	c	v	b	h	m	u	i	i	a
14	i	s	k	s	i	u	t	n	d	r	p	h	b	k	r
13	d	s	d	i	c	b	o	a	n	j	a	q	w	e	y
12	n	k	p	n	o	i	u	n	t	h	n	c	z	a	w
11	o	s	b	g	s	t	h	k	o	i	i	p	l	m	c
10	i	x	l	u	w	s	c	f	t	y	o	a	c	n	g
9	t	z	f	l	a	r	i	t	y	r	n	n	a	r	x
8	e	w	k	a	d	v	b	n	m	k	o	p	a	k	w
7	r	s	j	q	s	d	r	t	u	j	m	y	b	l	s
6	c	x	b	b	r	t	r	a	s	s	u	h	h	i	e
5	c	c	v	f	c	g	a	s	a	m	r	e	p	u	s
4	a	h	s	e	f	e	s	d	u	f	h	m	t	y	t
3	q	y	t	w	y	i	c	r	q	a	b	v	g	f	n
2	a	e	e	e	v	y	j	t	j	m	n	g	f	o	b
1	d	f	t	e	v	e	n	t	h	o	r	i	z	g	u
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

X

BEST COPY AVAILABLE

ANSWER KEY - LEVEL 1

BLACK HOLE GRIDLOCK

12	m							
11		a		x	r	a	y	g
10			t					r
9				t				a
8	p	u	l	l	e			v
7						r		i
6							f	t
5		s				s	u	y
4	j		t		s		e	
3	e		t	a			l	
2	t	o	m		r			
1	h			l	i	g	h	t
	A	B	C	D	E	F	G	H

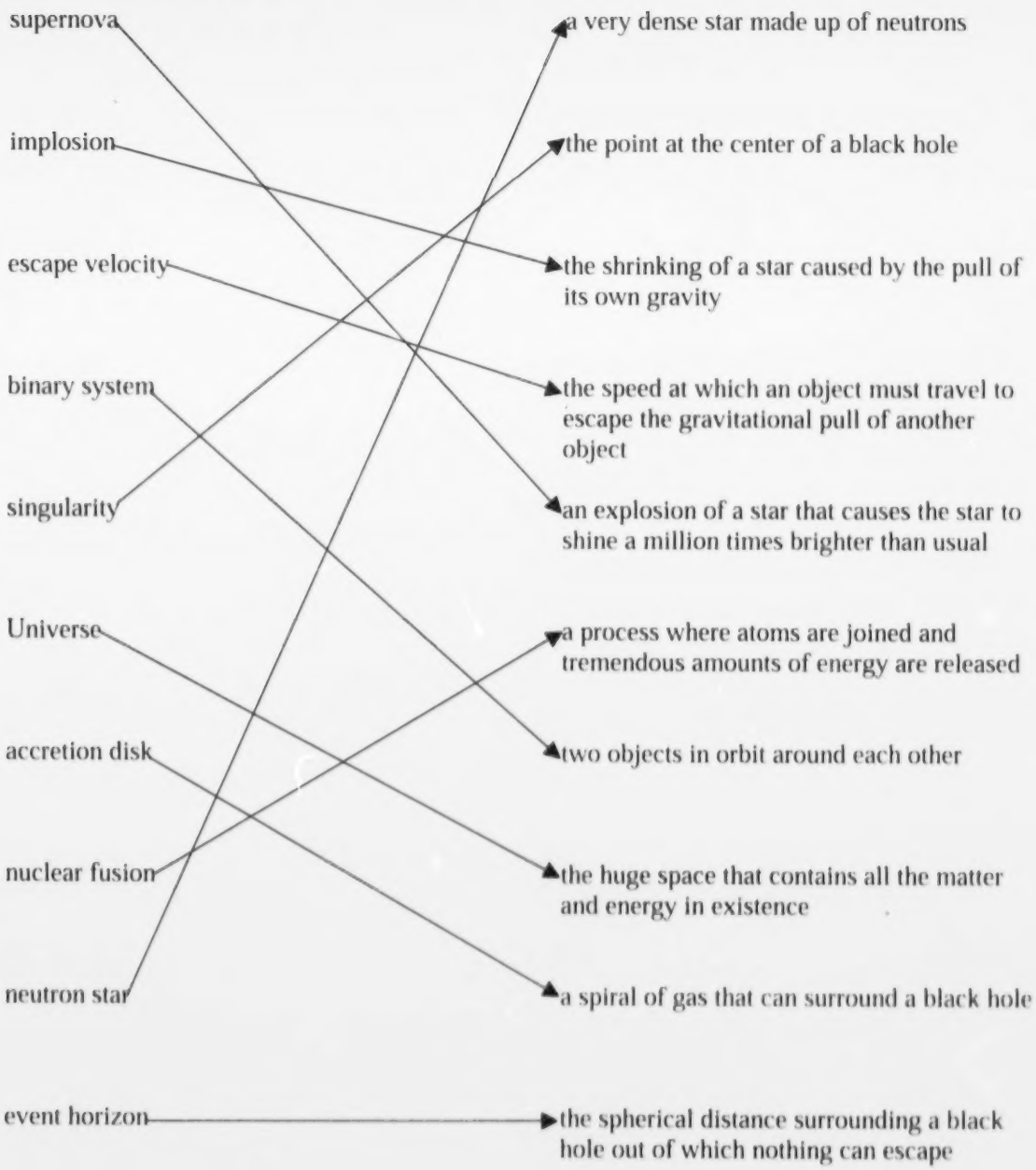
star - B5 C4 D3 E2
matter - A12 B11 C10 D9 E8 F7
fuel - G6 G5 G4 G3
X-ray - D11 E11 F11 G11
pull - A8 B8 C8 D8
gravity - H11 H10 H9 H8 H7 H6 H5
light - D1 E1 F1 G1 H1
mass - C2 D3 E4 F5
hot - A1 B2 C3
jet - A5 A4 A3

SUPERMASSIVE SUMS

1. 22
2. 5
3. 16
4. 25
5. 7
6. 14
7. 10
8. 14
9. 17
10. 21

Challenge:
11. 27
12. 17
13. 16
14. 32
15. 24

MATCH ME IF YOU CAN

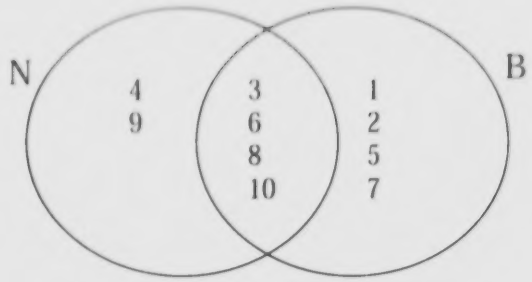

supernova
implosion
escape velocity
binary system
singularity
Universe
accretion disk
nuclear fusion
neutron star
event horizon
a very dense star made up of neutrons
the point at the center of a black hole
the shrinking of a star caused by the pull of its own gravity
the speed at which an object must travel to escape the gravitational pull of another object
an explosion of a star that causes the star to shine a million times brighter than usual
a process where atoms are joined and tremendous amounts of energy are released
two objects in orbit around each other
the huge space that contains all the matter and energy in existence
a spiral of gas that can surround a black hole
the spherical distance surrounding a black hole out of which nothing can escape

SPELLING STARS

b	f	h	n	w
bet	fill	hot	net	wet
bill	fall	hill	nest	west
ball		hall	not	will
best				wall

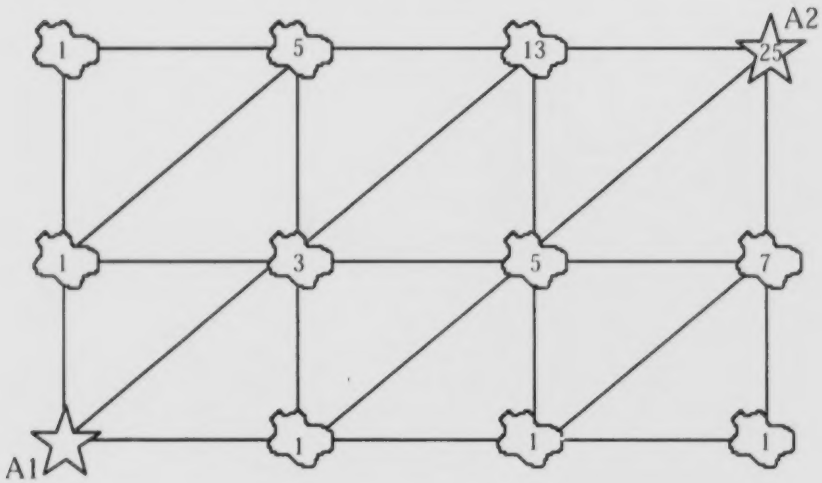
ANSWER KEY - LEVEL 2

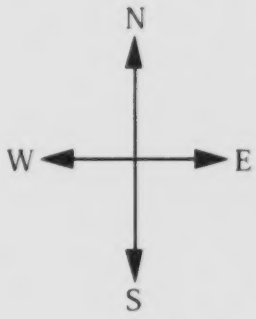
DIAGRAMMING DILEMMA



STAR ROUTES

Note the number of possible routes to each star or asteroid. The number of routes to the next object is equal to the sum of the routes that connect it.



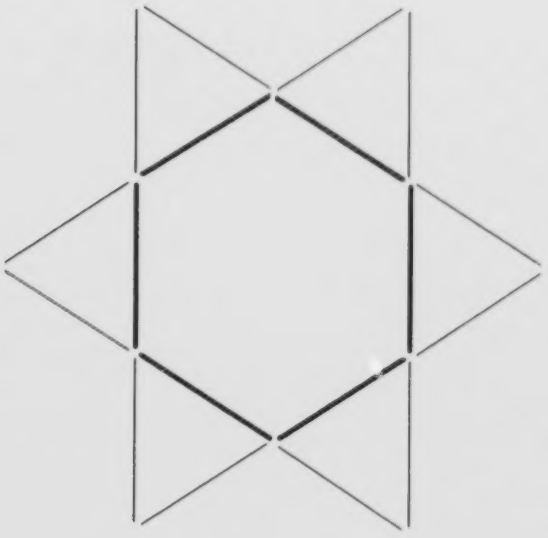


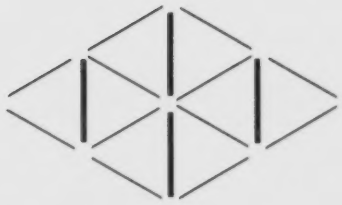
INTERGALACTIC INTEGERS

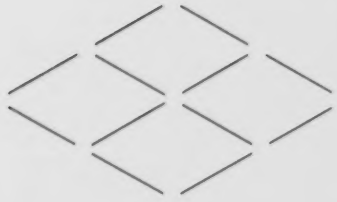
1. 28
2. 42
3. 94
4. -10
5. -21
6. -18
7. 26
8. -45
9. 19
10. 33

Challenge:
1. -14
2. -10
3. 10
4. -4
5. -14

DIAMONDS IN THE SKY







SCIENTIFIC NOTABLES

1. 1.5×10^{8} km
2. 9.5×10^{12} km
3. 1×10^{-33} cm
4. .0006 mm, 6×10^{-4} mm
5. 6.507×10^{8} km
6. 1.565×10^{9} Suns
7. 1.41 g/cm^3
8. 1.9×10^{6} g/ cm^3
9. 1.99×10^{33} g

Challenge:
Sun - 10.6 g
white dwarf – 1.4×10^{7} g
neutron star – 4.9×10^{15} g

SLOPES, STARS, SUPERNOVAE, AND STUFF

Y															
20															
19		g								p	l	r	i	h	w
18			r						o						
17				a				o			c				
16					v		l				o				n
15						i					m			i	a
14	i	s	k	s			t	n			p		b		r
13	d			i			o	a			a				y
12	n			n		i			t		n				
11	o			g	s					i	i				
10	i			u							o				
9	t		f	l	a	r	i	t	y		n	n		r	x
8	e												a		
7	r											y		l	
6	c					t	r	a	s						
5	c				c			s	a	m	r	e	p	u	s
4	a			e			s		u						
3			t			i			q						n
2		e			v									o	
1	d			e	v	e	n	t	h	o	r	i	z		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	X

1. gravitational - (2,19) (14,7) $s = \frac{7 - 19}{14 - 2} = \frac{-12}{12} = -1$

2. whirlpool - (15,19) (7,16) $s = \frac{16 - 19}{7 - 15} = \frac{-3}{-8} = \frac{3}{8}$

3. detect - (1,1) (6,6) $s = \frac{6 - 1}{6 - 1} = \frac{5}{5} = 1$

4. fusion - (3, 9) (8,14) $s = \frac{14 - 9}{8 - 3} = \frac{5}{5} = 1$

5. companion - (11,17) (11,9) $s = \frac{9 - 17}{11 - 11} = \frac{-8}{0}$ = no slope

6. accretion disk - (1,4) (3,14) $s = \frac{14 - 4}{3 - 1} = \frac{10}{2} = 5$

7. singularity - (4,14) (9,9) $s = \frac{9 - 14}{9 - 4} = \frac{-5}{5} = -1$

8. supermassive - (15,5) (4,1) $s = \frac{1 - 5}{4 - 15} = \frac{-4}{-11} = \frac{4}{11}$

9. event horizon - (4,1) (15,3) $s = \frac{3 - 1}{15 - 4} = \frac{2}{11}$

10. X-ray - (15,9) (12,7) $s = \frac{7 - 9}{12 - 15} = \frac{-2}{-3} = \frac{2}{3}$

11. binary - (13,14) (15,13) $s = \frac{13 - 14}{15 - 13} = \frac{-1}{2}$

12. quasar - (9,3) (7,6) $s = \frac{6 - 3}{7 - 9} = \frac{3}{-2}$

ABOUT THE POSTER

The *StarChild* Black Holes poster contains eight images which represent various artists' conceptions of different aspects of black holes. Below we give some additional information about each of the eight images.

Image #1
An artist's rendition of a binary system with an accretion disk. The accretion disk is formed as matter from the companion star is pulled into the black hole.

Image #2
This image is an artist's depiction of an active galaxy showing the supermassive black hole at its center. Particle jets can be seen streaming out perpendicular to the disk. This material streams away from the black hole just before it crosses the event horizon.

Image #3
An artist's rendition of the gravitational lensing effect that occurs when a black hole is located between the viewer and a light source (in this case, distant stars). The strong gravity of the black hole bends the path of the starlight to make the distant star appear to be located in a different place than it actually is.

Image #4
A depiction of the path a photon (or quantum of light) might follow as it spirals into the black hole.

Image #5
An artist's conception of an active galaxy with a supermassive black hole in its center, but without jets.

Image #6
An artist's depiction of a black hole's gravitational potential well. Einstein showed that the Universe can be thought of as a giant flat sheet of fabric called spacetime. Objects with mass put "dents" into the fabric. The depth of the dent is related to the mass of the object. A black hole creates such a deep dent that it essentially rips a hole through the fabric of spacetime.

Image #7
This rendition by an artist shows the spiraling of material from a normal star to a black hole. A hot spot is created where the new material hits the existing accretion disk and X-rays are emitted as the material spirals into the black hole and heats up.

Image #8
A depiction of matter gaining speed as it spirals toward the black hole. Once the material crosses the event horizon, it is no longer detectable.

RESOURCES

WEB SITES

http://imagine.gsfc.nasa.gov
An astronomy and astrophysics site for the high school and college student. It also contains lesson plans for math and science teachers. The site is maintained by the Laboratory for High Energy Astrophysics at NASA/GSFC.

http://www.phys.vt.edu/~astrophy/faq/blackholes.html
Dr. John Simonetti of the Department of Physics at Virginia Tech responds to questions about black holes frequently asked by K-12 students.

http://cfpa.berkeley.edu/BHfaq.html
Ted Bunn of the University of California at Berkeley responds in detail to frequently asked questions about black holes. Real life analogies are used to increase comprehension of abstract concepts.

http://www.ncsa.uiuc.edu/Cyberia/NumRel/BlackHoles.html
This is an online educational exhibit about black holes and their associated phenomenon provided by the University of Illinois.

http://starchild.gsfc.nasa.gov
The StarChild Web site is written by teachers for students in K-8. The site is continually updated and includes information on diverse astronomy topics including black holes. Activities are included in order to reinforce the concepts discussed in the text.

BOOKS

Kaufmann, William J. III, Universe, Freeman and Company, 1994.
This book is an excellent resource for teachers as it explains many astronomical concepts.

Mitton, Jacqueline and Simon, The Young Oxford Book of Astronomy, Oxford University Press, Inc., 1995.
This is an excellent general astronomy book for middle school and for high school students. Teachers will also find it quite useful for topics such as black holes and active galaxies.

Rosen, Sidney, How Far Is A Star?, Carolrhoda Books,Inc., 1992.
Cartoon characters make such difficult topics as black holes seem easy for elementary students in this entertaining and educational book.

Couper, Heather and Henbest, Nigel, Black Holes, Dorling Kindersley Publ., 1996.
A colorful introduction to the many strange behaviors and appearances of black holes. Intended for middle school to high school levels.

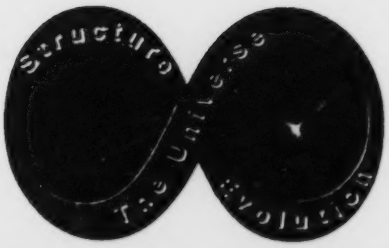
Novikov, Igor, Black Holes and the Universe, Canto Edition, Cambridge University Press, 1995.
This book contains a non-technical discussion of relativity and astrophysics. It is an excellent teacher resource that may also be usable to a capable middle school and high school student. Topics included in the book range from black holes to quantum theory.

VIDEOS

• Mysteries of Deep Space, "Exploding Stars and Black Holes", PBS Home Video, Turner Home Entertainment (60 minutes). This is a well-told story that explains the life cycle of massive stars that will eventually die as black holes. Intended for the high-school student and above.

• "Search For Black Holes", New River Media (60 minutes). This is a video that contains interviews with all of the "who's who" in black holes today. Some of the animations are quite clever. Intended for the middle-school student and above.

• Stephen Hawking's Universe Series, "Black Holes and Beyond" (60 minutes). The animations in this video are very attractive. Intended for the high-school student and above.



Produced by
NASA Goddard Space Flight Center
Laboratory for High Energy Astrophysics